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MICROBIOLOGICAL EVALUATION OF PRODUCTION PROCEDURES FOR FROZEN FOIL PACK MEALS AT THE CENTRAL PREPARATION FACILITY OF THE FRANCIS E. WARREN AIR FORCE BASE

January 1976

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UNITED STATES ARMY
NATICK RESEARCH and DEVELOPMENT COMMAND
NATICK, MASSACHUSETTS 01760

Food Sciences Laboratory

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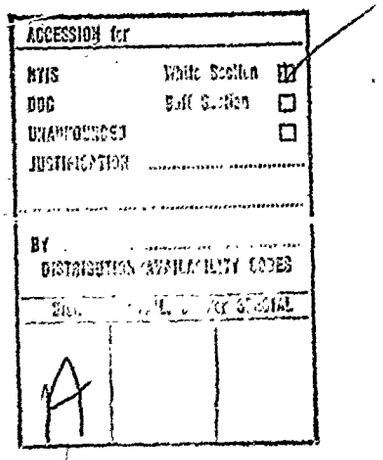

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Food items produced at F.E. Warren AFB met the microbiological constraints of SAC Regulation 146-1. A Hazard Analysis (HA) to aid in production guidance was of limited value due to a lack of predictability of production procedures and would be of maximum utility only if quality was maximized. Sanitation was generally satisfactory but a lack of consistency in sanitizing surfaces was evident. In addition, gloves were not used for filling operations and items were sliced on cutting boards containing large numbers of *Pseudomonas aeruginosa*. Recommendations are made of improving current production procedures and for a new program.

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to enable a realistic HA to be obtained and for making the laboratory more efficient. Evaluation of Rodac plates and the modified swab test using a Millipore Corp. Total Count Water Tester indicates that they would be a valuable adjunct to a monitoring system. The lack of formal and consistent processing routines whereby time and temperature during processing is carefully controlled and product quality optimized prevented a HACCP analysis by NDC personnel.

SUMMARY

The APC's of the six raw beef and chicken samples used for foil pack meals varied from 10^4 to 10^6 CFU/g with all having over 100 CO/g and FC counts of 4.6 to over 1100/g. Four samples contained *S. aureus* and all contained fecal streptococci though, in both cases, in low numbers. Vegetables and potato had APC's of less than 10^4 CFU/g, less than one CO/g and no FC.

Processing reduced the microbial populations to acceptable levels. Of the 16 items analyzed all had APC's of less than 10^4 CFU/g, 14 with less than 10^3 CFU/g. Coliform organisms were absent in 14 samples and none had over 10/g. All 16 cooked items were devoid of FC and *S. aureus* organisms.

Processing time varied from 65 to 420 min. Some items were held for 80 to 190 min at temperatures of 140 F to 192 F (60 to 89 C).

Individual items of equipment were evaluated by RODAC plates and by swabs for their sanitary quality. Satisfactory ratings for individual items varied from 32 to 87%. The overall average incidence for satisfactory ratings was 61%. Dominant cultures of *P. aeruginosa* were found on cutting boards. The lack of a formal and consistent processing routines whereby time and temperature during processing is carefully controlled and product quality optimized prevented a HACCP analysis by NDC personnel.

PREFACE

In response to Air Force Requirement 4-2 the Food Microbiology Group, Food Sciences Laboratory, Natick Development Center (NDC) initiated a study at the Francis E. Warren AFB, Cheyenne, Wyoming. At this base food items for the frozen foil pack meal is processed, packaged, frozen and shipped to missile sites in a six state area. At the missile site different combinations of entree, vegetable, potato and dessert are selected by the individual for reconstitution and consumption. The objectives of the study were to:

1. Conduct microbiological analysis of food ingredients during processing.

2. Correlate the microbiological quality of the food ingredients during processing with processing parameters and sanitation.

3. Conduct a hazard analysis (HA) of the processing operations.

4. Make recommendations for improving currently employed quality control procedures and techniques.

The intent was to conduct the study in two phases. The initial phase to be a HA of the facility and to make recommendations for defining and monitoring critical control points (CCP). An additional study would then be made to verify the validity of the recommendations and implemented procedures.

This report will be concerned with the data obtained during the initial phase.

The authors wish to thank Sgt. B. D. Fisher for his laboratory assistance and LTC. Anderson, Capt. Tate, Capt. Peterson, Sgt. Tillman and the staff of the CPF for their cooperation during this study.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS IN APPENDIX

LIST OF TABLES

LIST OF TABLES IN APPENDIX

MICROBIOLOGICA EVALUATION OF PRODUCTION PROCEDURES FOR FROZEN FOIL PACK MEALS AT THE CENTRAL PREPARATION FACILITY OF THE FRANCIS E. WARREN AIR FORCE BASE

INTRODUCTION

The frozen foil pack meal (FFPM) program was designed to feed nutritious and varied meals of uniform quality to personnel assigned to Minuteman missile sites. Breakfast, salads and beverages are prepared conventionally by a cook and all other items are obtained as a precooked, frozen individual serving which was prepared in the Central Preparation Facility (CPF) at F.E. Warren AFB, Cheyenne, Wyoming. The production, storage, distribution and reconstitution of the precooked frozen food items are governed by SAC regulation 146-1, 20 February 1974. Since all personnel in the Minuteman system consume food items prepared at one source, the procedures used for insuring their safety from microbial intoxication and infection must have a high degree of reliability.

The most effective way to increase and maintain reliability is to identify those processing stages that are considered to present microbiological problems and to devise methods for minimizing or eliminating potential hazards. This is the basis for the hazard analysis, critical control point (HACCP) program devised by the FDA and USDA for food processors and found to be of particular value for the frozen food industry. Most large industrial food processors are particularly suited to the HACCP approach since each processing line is designed for a particular product and rigid production and sanitation guides are utilized. While the principles governing HACCP are general, each application must be quite specific, being designed for specific facilities and products.

Products at F.E. Warren AFB are monitored by end-product analysis and by using regulations based on general principles as a guide to good manufacturing practices (GMP). The CPF at the F.E. Warren AFB did not lend itself to conventional HACCP analysis, not due to any inate complexity, but to a lack of uniformity as regards to material flow and equipment usage. This subject is dealt with more fully in the discussion.

EXPERIMENTAL PROCEDURE

MICROBIOLOGICAL ANALYSIS

Unless otherwise indicated, prepared and appropriately packaged culture media was obtained from the General Hospital Technology Corporation, Andover, MA, shipped by air freight to Denver, Co., and then by truck to the F.E. Warren AFB at Cheyenne, Wyoming. The media was then unpacked and refrigerated.

Food samples were prepared for analysis by the Colworth "stomacher" apparatus (A. J. Seward and Col, London, Ltd) using 0.1% trypticase soy broth, pH 7-7.2 (BBL) as the diluent.

The analysis for aerobic plate count (APC), coliform (CO) fecal coliform (FC) and fecal streptococci organisms were performed by the methods described in the Food and Drug Administration's "Bacteriological Analytical Manual" (BAM) with the modification of replacing the phosphate buffered diluent with 0.1% trypticase soy broth. A 10 ml aliquot, of the 1:10 dilution of food slurry (equivalent to 1 g of food) was the initial inoculum for the most probable number (MPN) test used for determining CO and FC.

Staphylococcus aureus was assayed by the MPN technique. A 1, 0.1 and 0.01 g sample of the slurry (10, 1 and 1 ml of appropriate dilutions) were pipetted into trypticase soy broth supplemented with 0.5% yeast extract. After 2 hrs at 37 C an equal volume of TSY broth containing 20% NaCl was added to each tube to give a final NaCl concentration of 10%. This procedure was used to permit recovery of cells damaged by processing. After 24-48 hr incubation at 37 C each tube was steaked onto Baird-Parker agar (BAM), incubated at 37 C for 24 hr and presumptive colonies were selected for confirmation by the gram stain, catalase, the coagulase test, the presence of DNase and by microscopic examination.

Isolates suspected of being *Pseudomonas aeruginosa* were grown in trypticase soy broth (BBL) at 42 C overnight and streaked onto cetrimide agar (Kominos *et al.*, 1972) and examined for growth and for the presence of blue-green fluorescence when irradiated with ultraviolet light and by growth in nitrofurantoin. For confirmation all presumptive isolates had to also be gram negative, motile, oxidase positive rods.

Samples for analysis were collected in either sterile whirl-pak bags (Scientific Products) or, if obtained after processing, in their sealed foil container and stored in crushed ice. Samples were analyzed within 12 hr of collection.

In order to evaluate aersol particle fall-out during processing foil containers containing a 0.5 in (12.7 mm) layer of trypticase soy agar with 0.5% yeast extract were

sterilized and substituted for a filled container in the sealing operation. The sealed containers were then incubated at ambient temperature for 48 hrs prior to counting.

SANITATION

Rodac Plate Analysis

Rodac plates were tempered at ambient temperature at least 24 hrs prior to use. For large surfaces such as tables, 10 plates were always used for evaluation; for smaller surfaces such as cutting boards, kettles, and pans 5 Rodac plates were generally employed. One to 2 plates were used for small unit items such as spoons, spatulas, and knives.

Surfaces were usually examined by uniformly distributing the Rodac plates over an entire surface. As examples the following patterns were used for tables, cutting boards and pans in "distributive" patterns.

Table:

```
    x     x     x
 x     x     x     x
    x     x     x
```

Cutting board, pan:

```
    x     x
       x
    x     x
```

To test the validity of the above distributions surfaces immediately adjacent to an area tested by a Rodac plate were also examined by 5 or 10 additional Rodac plates. These latter plates were adjacent to each other in a limited area in the following "intensive" patterns:

```
x  x  x
x  x  x          x  x
x  x  x  x;      x  x  x
```

After exposure all plates were incubated at ambient temperature for 24-28 hrs.

Swab Method

Surfaces for which Rodac plates were unsuitable for testing were examined by the swab technique. The cotton swabs and buffered rinse solution employed were those recommended by the American Public Health Association (Standard Methods for the Examination of Dairy Products, 1972).

Surfaces were evaluated according to the following scheme: ladles and spoons, unless noted otherwise had the top surface and the portioning end swabbed; the entire edge of the flexible blade of the squeegee was swabbed; the packaging lines had the inner surfaces of the rim guide rails and approximately 25.8 cm^2 (4 in^2) of the metal plates in the capping area swabbed; bowls, kettles, etc., had approximately 25.8 cm^2 of the inner surface swabbed. After swabbing the moistened swab tip was broken off into a test tube containing 10 ml of buffered rinse solution and the tube shaken 50 times. The contents were then poured into the plastic case of a Total Count Water Tester (Millipore Corp., Bedford, MA, TCWT) and additional rinse solution added for a total volume of 18 ml. The tester was then immersed into the rinse solution for 30 sec, the liquid in the case poured out, the tester reinserted into the empty case and incubated at ambient temperature for 18-24 hrs and then at 37 C for an additional 24 hrs before being counted. The number of colony forming units (CFU) per unit area swabbed was obtained by multiplying the CFU per tester by 18.

Water was analyzed by the direct TCWT technique.

Air Sampling

Air samples were collected adjacent to table 23 (Figure I, Appendix). A Reynier Air Slit Sampler unit, model FD-100-A was employed with the distance between the slit and the surface of the agar plate containing trypticase soy agar (BBL) supplemented with 0.5% yeast extract set at 2 to 3 mm. The meter on the vacuum pump was adjusted for an air flow through the slit of 1 ft^3/min (0.028 M^3/min.). The plates were incubated at ambient temperature for 24 hrs and for an additional 24 hrs at 37 C prior to counting. The counts are expressed as CFU per 5 minutes.

A Weston thermometer (Model 2292; ± 2 F; ± 1.1 C) was used to measure temperature.

MONITORING CRITERIA

Microbiological

The following microbiological requirements for sample units within a lot of a precooked frozen foil packed item were used in accordance with SAC Regulation 146-1:

Aerobic plate count (APC)	$\leqslant 1 \times 10^5$ CFU/g
Coliform organisms	$\leqslant 1 \times 10^2$ /g
Escherichia coli	negative in 1 g

No criteria were used for *Staphylococcus aureus* or fecal streptococci.

Sanitation

The following definition was used when evaluating surfaces by Rodac plates: The surface was considered satisfactory if half or more of the plates (25.8 cm^2) contained 50 or less CFU/plate with no plate exceeding 100 CFU.

No criteria were used for either swabbed surfaces or air monitors.

Temperature

As specified in SAC Regulation 146-1 the temperature of the food for the filling operation should initially be at or above 140 F (60 C) or below 45 F (7 C). The duration of the filling and sealing operation of any given item should not exceed 20 minutes.

RESULTS

MICROBIOLOGICAL ANALYSIS

The initial APC indicated that the ingredients had less than the number of organisms usually considered as necessary for the development of spoilage odors (Table 1). All six samples of beef and chicken possessed over 100 CO/g and from 4.6 to over 1100 FC/g. Four of these samples also contained *S. aureus* and all contained fecal streptococci, although in low numbers. The three processed vegetables and potato samples had low APC's, low CO's, and none contained FC or *S. aureus*. Two of the mixes, of widely different APC and CO counts, contained low numbers of FC organisms. The raw potato sample had a high APC of over 10^5 CFU/g and almost 500 CO/g but no FC organisms.

The subsequent formulation, blending and processing resulted in products having less than $1x10^4$ CFU/g. (Table 2, Figures 1-9). In fact, of the 16 products analyzed 14 contained less than $1x10^3$ CFU/g. Two samples, country steak and O'Brien potato, had less than 10 CO/G all the others being negative. Meat loaf and country steak were the only foods that contained any fecal coliforms and these two samples contained less than 1 FC/g. None of the samples contained *S. aureus* and all had less than 10 fecal streptococci per g.

The two samples, meat loaf and country steak, that contained FC organisms in the finished product also had them in the raw ingredients. The ground beef used for meat loaf had over 1100/g but the raw steak and seasoning used to formulate country steak had less than 10/g. All of the temperatures monitored for these 2 products just prior to portioning and sealing were in excess of 140 F (60 C) and the highest temperature noted was 192 F (89 C).

TABLE 1

Microbiological analysis of ingredients used in frozen foil pack food items

Item	Aerobic plate count CFU[a]/g	Coliform MPN[b]/g	Fecal coliform MPN/g	*S. aureus* per gram	Fecal streptococci per gram
Raw beef	5.2×10^5	>1100	4.6	+	69
Ground raw beef[c]	2.4×10^6	>1100	>1100	+	2
Ground raw beef[d]	3.8×10^5	870	> 110	+	2
Raw steak[d]	3.4×10^4	234	8.8	+	12
Raw chicken	3×10^4	110	89	–	1.5
Raw chicken	1.2×10^4	240	24	0	2
Peas and carrots	1.1×10^4	0.36	0	0	–
Green beans	4×10^2	0	0	0	0
Raw potato	3.8×10^5	470	0	0	5
Potato (dehydrated)	$<10^2$	0	0	0	0
Gravy mix[e]	5×10^1	15	1.5	0	0
Seasoning mix[e]	4.1×10^4	350	2.7	–	23
BBQ sauce mix	2.5×10^2	0	0	0	0
Rehydrated cake mix	6.7×10^2	17	0	0	0
Icing for cake	24×10^3	0	0	0	0

[a]Colony forming unit

[b]Most probable number

[c]For meat loaf of Table 2

[d]For salisbury steak of Table 2

[e]For O'Brien potatoes of Table 2

TABLE 2

Analysis of processed items[a]

	Frozen[b]	Aerobic plate count CFU[c]/g (x 10^2)	Coliform MPN[d]/g	Fecal Coliform MPN/g	Temperature[e] range during thermal processing °F	°C
Pork chop suey	–	2.8	0	0	–	–
Roast pork	–	< 1	0	0	–	–
Roast turkey	–	< 1	0	0	–	–
Beef pot pie	–	< 1	0	0	176/192	80/89
Beef pot pie	+	6.8	0	0	–	–
Meat loaf	+	9.5	0	0.8	138/166	59/74
Salisbury steak	+	23		0	156/192	69/89
BBQ chicken	–	< 1	0	0	180/190	82/88
Chicken – baked	–	27	0	0	172/192	78/89
Chicken – fried	–	<10	0	0	166/176	74/80
Macaroni and cheese	–	1.3	0	0	–	–
Country steak	–	< 1	0.5	0.1	138/168	59/76
Green beans	–	< 1	0	0	180	82
Potato – O'Brien	–	< 1	1.4	0	158	70
Cake – chocolate	–	2.2	0	0	176	80
Cake – plain	–	<10	0	0		

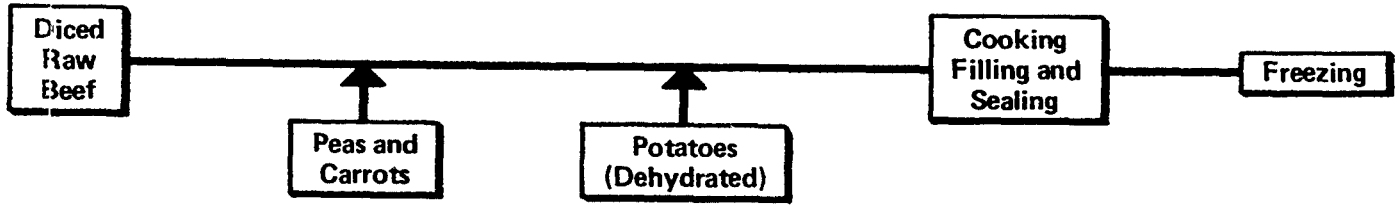
[a]All items were negative/g for *Staphylococcus aureus* and contained less than 10/g of fecal streptococci.

[b]Sampled either after freezing (+) or after capping and sealing but prior to freezing (–).

[c]Colony forming units.

[d]Most probable number.

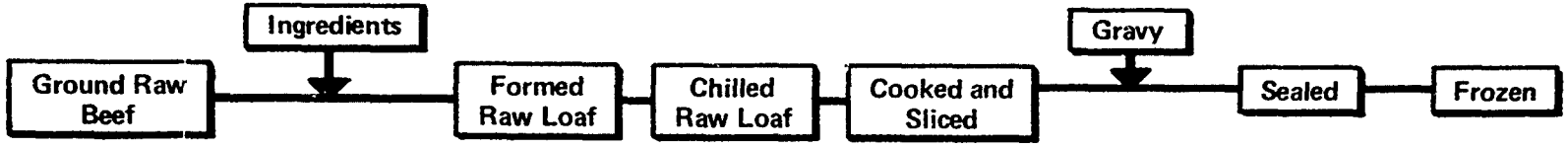
[e]The range noted during processing and prior to freezing.



APC[a]	5.2×10^5	1.1×10^4	5.5×10^4	$< 10^2$	$< 10^2$
C	> 1100	0.36	0	0	0
FC	4.6	0	0	0	0
SA	+	0	0	0	0
FS	69	0	0	0	0
MIN	0		75	190–300	
°F		148–174		176–192	
°C		64– 79		80–89	

[a]Aerobic plate count in colony forming units (CFU)/g; C-coliform in most probable number (MPN)/g; FC-fecal coliform in MPN/g; SA-*Staphylococcus aureus*/g; FS-fecal streptococci/g; MIN-minutes to reach the particular stage of processing; °F-degrees Fahrenheit; °C-degrees Celsius.

Figure 1. The effect of processing on the microflora of beef pot pie

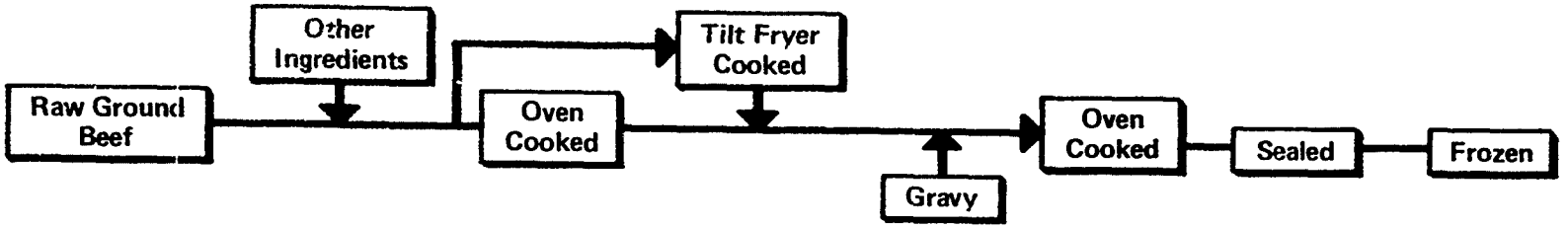


APC[a]	2.4×10^6		1.3×10^6	1.2×10^6			2.4×10^3	9.5×10^2
C	> 1100		> 1100	> 1100			0	0
FC	> 1100		> 1100	> 1100			0.8	0
SA	+						0	0
FS	2		4	3			< 10	< 10
MIN	0	15	125	240	420			
°F			54--60	48–60	138–166	186[b]		
°C			12–16	9–16	59–74	86[b]		

[a]See figure 1.

[b]Refers to gravy.

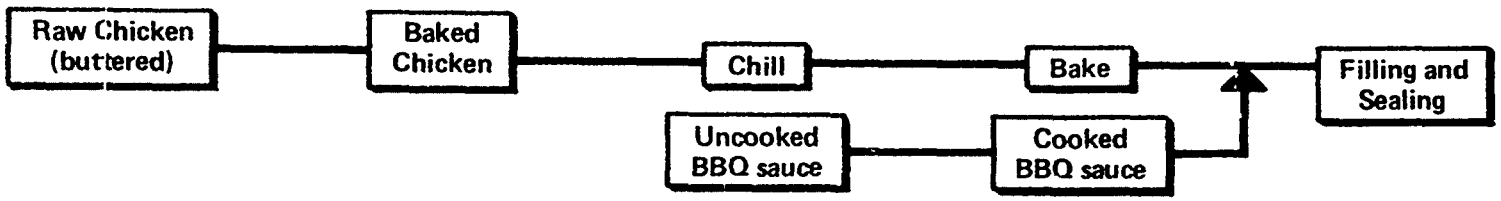
Figure 2. Microflora during processing of meat loaf



APC[a]	3.8×10^5	6.5×10^5	6.9×10^3	5.5×10^3			$< 10^2$	2.3×10^3
C	870	> 1100	0	0			0	0
FC	> 110	> 110	0	0			0	0
SA	+		+	0			0	0
FS	2	4	0	0			0	0
MIN	0	10	75	75	110		165	
°F		48–52	162	140–152	192	194	156--192	
°C		9–11	72	60–67	89	90	69–89	

[a]See figure 1.

Figure 3. The effect of processing on the microflora of salisbury steak

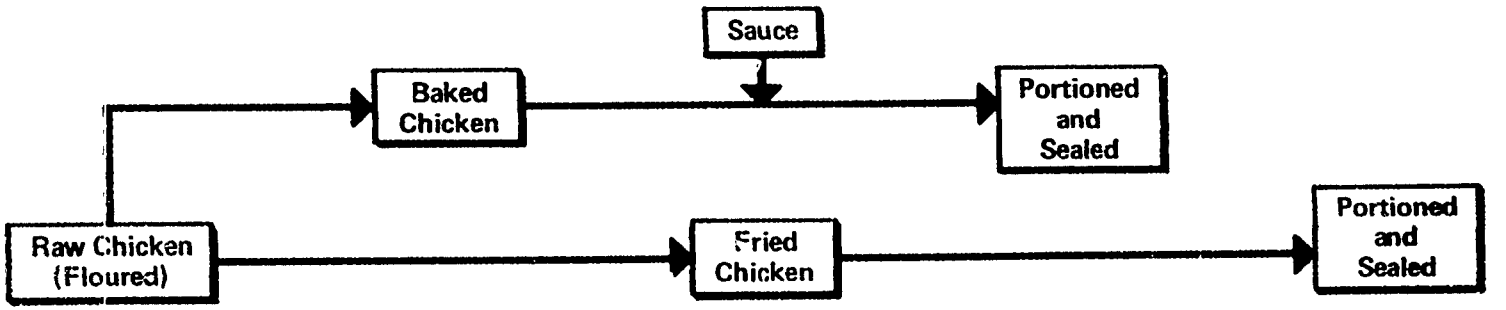


APC[a]	3.0×10^4	< 100	$2.5^b \times 10^2$	$< 10^2$
C	110	0	0	0
FC	89	0	0	0
SA	–	0	0	0
FS	1.5	< 10	0	0
MIN	0	60		210–360
°F	36	146–190		180–190
°C	2	63–88		82–88

[a]See Figure 1.

[b]Applies to BBQ sauce.

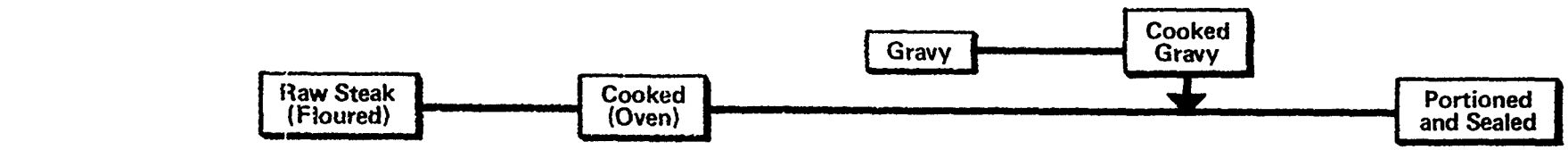
Figure 4. *The effect of processing on the microflora of BBQ chicken*



APC[a]	1.2×10^4	2.3×10^3	7.5×10^3	2.7×10^3	$< 10^3$
C	240	0	0	0	0
FC	24	0	0	0	0
SA	0	0	0	0	0
FS	2	< 10	< 10	< 10	< 10
MIN		45	75	170–185	285
°F		170–185	182	172–192	166–176
°C		77–85	83	78–89	74–80

[a]See figure 1.

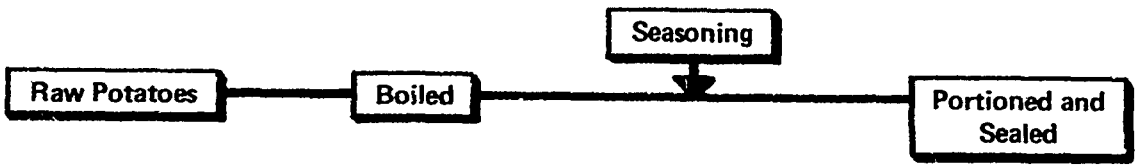
Figure 5. The effect of processing on the microflora of baked and fried chicken



APC[a]	3.4×10^4	6×10^3	$< 10^2$		$< 10^2$
C	234	0.8	15		0.5
FC	8.8	0	1.5		0.1
SA	+	0	0		0
FS	12	< 10	< 10		< 10
MIN		60		100	140
°F		138–160		185	150–168
°C		59–71		85	66–76

[a]See figure 1.

Figure 6. Microflora during processing of country steak



APC[a]	3.8×10^5		4.1×10^4 [b]	$< 10^2$
C	470		350	1.1
FC	0		2.7	0
SA	0			0
FS	5		23	< 10
MIN		60		65
°F	40		70	158
°C			21	70

[a]See figure 1.

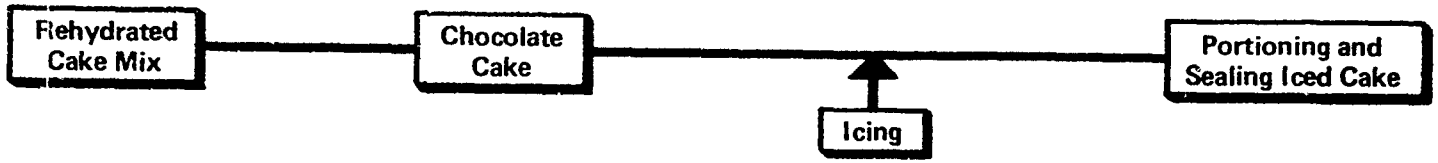
[b]Refers to seasoning only.

Figure 7. The effect of processing on the microflora of O'Brien potato

APC[a]	4×10^2		$< 10^2$
C	0		0
FC	0		0
SA	0		0
FS	0		0
MIN	0	165	245–275
°F			180
°C			82

[a]See figure 1.

Figure 8. The effect of processing on the microflora of green beans



APC[a]	6.7×10^2	50	24×10^2	2.2×10^2
C	17	0	0	0
FC	0	0	0	0
SA	0	0	0	0
FS	0	0	0	0
MIN	0	30	85–125	
°F		176	RT[b]	RT
°C		80		

[a]See figure 1.

[b]Room temperature.

Figure 9. Microflora during processing of chocolate cake

In one instance (Figure 2) raw, formulated and shaped meat loaf was refrigerated at 50-60 F (9-15 C) for 2 hr until ovens became available. This did not result in an increase in the APC or in FC.

The processing time varied from 65 min for O'Brien potatoes to 420 min for meat loaf (Figures 1-9). In a number of instances products were kept for 80 to 190 min at temperatures of 140 to 192 F (60 to 89 C) until capped and sealed.

SANITATION

Rodac Plate Evaluation

Satisfactory clean-up operations were achieved with an overall monitoring average incidence of 61% (Table 3; Table I, Appendix) varying from 32% for cutting boards to 74% for tables. Excessive numbers, appearing at times as a pure culture of *Pseudomonas aeruginosa*, were isolated from cutting boards. Although the hot tap water was sufficiently high in temperature (165-170 F; 74-77 C) and quantity, a number of items were not consistently sanitized. These included wooden rolling pins, spatulas, cutting boards and portions of the capper and sealing machine. In one instance one side of a cutting board was satisfactory while the other was found to be unsatisfactory.

There doesn't appear to be any difference between evaluating a surface by the intensive and distributive techniques (Table II, Appendix). Of the 13 surfaces evaluated disagreement occurred twice. In one instance the disagreement was due to an isolated area of higher microbial density not detected by the intensive technique. In the second instance, while both methods verified a generally poor sanitizing effort, the intensive method, while actually having a higher average, was marginally satisfactory.

Swab Method

Surfaces on the small packaging line, dippers and serving spoons often possessed high microbial populations (Table 4). For many surfaces the swab counts varied up to 100 fold between different sampling periods.

Air Sampling

The microbial concentration in the atmosphere had not, with the exception of 3 June 1974, exceeded 70 CFU/5 min (or 15 CFU/ft^3, 0.028 m^3, Fig. 10). There did not appear to be any direct relationship between the activities of personnel and the microbial population in the atmosphere. It was noted that during production on 30 May a filling apparatus was being installed and a large oven, including its insulation, was being dismantled and removed (locations 22 and 28 respectively, Figure I, Appendix). These activities did not result in a noticeable increase in microbial concentration in the atmosphere.

TABLE 3

Evaluation of equipment surfaces by Rodac plates

Item	Percentage	
	Satisfactory[a]	Unsatisfactory
Table	74	26
Utensil	42	58
Pot and pan	87	13
Cutting board	32	68
Small packaging line	67	33
Large packaging line	65	35
Average	61	39

[a]See text for the definition of satisfactory and unsatisfactory surfaces.

TABLE 4

Evaluation of equipment surfaces by swabs

	Average CFU per unit surface or volume[a]					
	May			June		
	28	29	30	3	4	5
Laddle[b]		201[d]		230[e]		
Laddle (strainer)			0		234	
Squegee			126			
Mixing bowl			306			
Kettle			72			54
Dipper			180		2556[g]	144[i]
Serving spoon[c]					504	558[m]
SPL[k] Beginning	990					
End	>3600			2570[f]	>2700	3744[h]
Front plate				198		
Side plate	4914			7740		
Capper plate	324					
LPL[l] End	194	342	135	54	243	81
Front plate			243	0		
Side plate	504	18	990	18		
Capper plate	288	0				
Tap water						90[j]

[a]For swabbing techniques see text.

[b]Inside surface.

[c]Both surfaces.

[d]Average of 72, 126, 180, 216, 306, 378 CFU/ml; each value representing a separate laddle.

[e]Average of 72, 90, 288, 396, 306 CFU/ml each value representing a separate laddle.

[f]Average of 2 swabs, 1 from each guide rim; 4860, 270 CFU/ml.

[g]Average of 414, 162, 9432 and 216; each representing an individual unit.

[h]An average of the inner surface of both guide rims; 468, 7020 CFU/ml.

[i]Average of 252, 126, 90, 18, 270, 108 CFU/ml with each value representing a one swab per dipper.

[j]Average of 260, 99, 18, 22 CFU/ml.

[k]Small packaging line.

[l]Large packaging line.

[m]An average of 2 spoons; 18, 1098 CFU/ml.

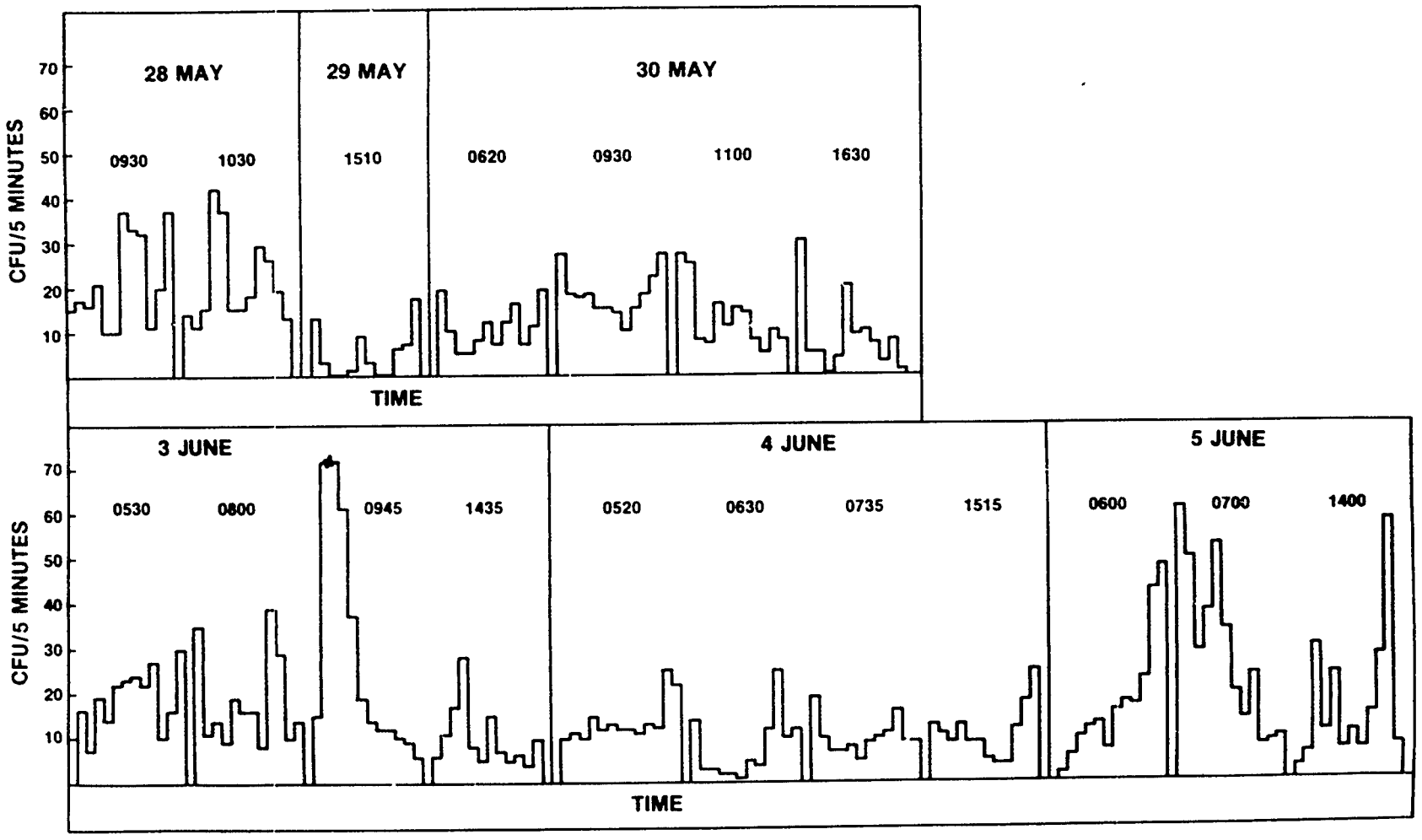


Figure 10. Air sampling in the vicinity of the Filling Operation.

Each interval is a 5 minute increment and the time indicated refers to the initial time of the 1 hr. sampling period.

The technique for evaluating the extent of atmospheric fall-out during the filling and sealing operation by sending foil containers containing sterile agar through the packaging line in place of the food item indicated low levels of contamination from this source. The highest number of colonies per container found were 3 and the agar in over half of the foil units was devoid of colonies.

A listing of observations which were indicative of poor manufacturing practices is presented in the Appendix.

DISCUSSION

It is evident that the CPF facility at F.E. Warren AFB has the capability to process meals within the constraints imposed by SAC regulation 146-1. The FC found in meat loaf and country steak (Table 2), less than 1/g, would not have been detected unless the equivalent of 1 g of food was used in the initial dilution. These were the only two items for which a processing temperature of 150 F (66 C) or below were noted.

The combination of microbiological constraints of SAC regulation 146-1 may encourage excessive thermal processing which can be detrimental to good organolyptic qualities. Examination of the microbial population of the ingredients used (Table 1) indicates that the highest APC was 2.4×10^6/g and the highest CO and FC counts were in excess of 1×10^3/g. The actual values for the latter two indices may conceivably be in excess of 10^4 MPN/g. It can be seen that in order to decrease the three requirements to 1×10^5/g, 1×10^2/g and 0/g, respectively, in the final product, one must actually design the process for eliminating at least 4 logarithmic orders of magnitude of FC but only about 1.5 to 2 orders of the aerobic microbial population.

Using the APC as a measure of thermal destruction of the general aerobic microflora at least a 3 to 5 logarithmic decrease in population occurred during processing.

One method for increasing the certainty that an established thermal processing procedure will result in acceptably low level of microorganisms is to use only raw materials containing an acceptably low microbial population. A number of industrial suppliers are required to meet microbial constraints on raw materials. The state of Oregon has imposed limits of an APC of 5×10^6 CFU/g of ground meat, 1×10^6 CFU/g in processed meats and 50 and 10 MPN/g of *Escherichia coli* respectively. Canada has proposed standards based on the approach of the International Commission on Microbiological Specifications for Foods (ICMSF, 1974). Of 5 samples of raw hamburger tested, 2 should not exceed 1×10^7 CFU/g, 3 can exceed this number but no sample may exceed 5×10^7 CFU/g. For *E. coli*, 2 of the 5 samples should be below 100/g and none may exceed 500/g. Standards for *S. aureus* require 3 samples to be below 10^2/g none exceeding 10^3/g Salmonella must be absent in 25/g in all 5 subsamples.

While the ground beef samples used in this study, Table 1, would have been within constraints imposed by Oregon state as regards to APC they would not have satisfied the constraints of *E. coli*. The samples were not analyzed for Salmonella.

It should be noted that while the FC counts are not identical to an enumeration of *E. coli*, the use of EC broth at 45.5 C favors the enumeration of Type I *E. coli* (++−−) strains rather than those indol negative type II (−+−−) strains, although irregular type II and VI can also be included. In addition a number of typical indol producing *E. coli* type I strains are known to be anaerogenic in lactose broth at either 37 or 45 C.

The only samples to contain FC were the country steak and the meat loaf. The APC's were extremely low for these samples. These products were both found to be below 150 F (66 C) during processing. Fecal coliforms do not proliferate at 138 F (59 C) and would tend to die out if held at these temperatures. The failure to eliminate FC from the meat loaf may also have been due to improper oven loading of the loaves for baking resulting in poorer heat penetration. The pans containing the steaks also tended to be overloaded. The meat loaf was hand sliced on cutting boards which were, as previously noted, unsanitary and contained large numbers of *P. aeruginosa*. One batch of country steak was found by the monitors to be cooked to an average temperature below 140 F (60 C) and was subsequently reheated. Other than this instance there is no obvious explanation for the presence of FC in the steak.

The limited study of the number of Rodac plates and the distribution to be used for sampling indicates that distributing the plates over the entire area is more effective. The Rodac plate counts in this study indicated a fairly uniform distribution of contaminants over any particular surface. Other studies by the authors had indicated considerably more non-uniformity. With uniformity in the distribution of contaminants a smaller number of Rodac plates could have been used for evaluation.

It is difficult to relate Rodac plate counts to swab counts. The swab technique not only tends to remove organims by friction but to disrupt clumps. The USDA considers an acceptable aerobic count of 30/in^2 (6.45 cm^2) in food plants as acceptable, and 100/in^2 as "highly suspect". Therefore, anything over 120 or 400/4^2 in^2 (25.8 cm^2) should be translatable to a comparable constraint when Rodac plates were used. It is apparent that more data will have to be collected to resolve this matter. In certain instances, swab counts were extremely high. Interestingly, swab testing indicated that the small packaging line was never satisfactorily sanitized, whereas the large packaging line almost always had much lower counts. When tested by Rodac plates, however, both lines reflected poor clean-up efforts. In previous tests of the efficacy of TCWT to quantify microorganisms about 30 to 50% less organisms were recovered by this technique as compared to conventional plating.

In attempting to minimize the product rejection rate a decision had been made to process and hold production items at temperatures of 180 F (82 C) or above, especially during the filling and capping operation. This treatment can result in a thermally abused product. The question remains as to whether the F.E. Warren AFB facility has the capability to consistently and efficiently produce products of optimal quality that are microbiologically safe without a more rigid quality control program.

The problem which motivated this study was a period of non-compliance of production items with the microbiological constraints of SAC Regulation 146-1. An expedient program was instituted whose main feature was the maintenance of high cooking and post-cooking holding temperatures. Subsequently, whenever the capping machines were in use and a back-up of cooked items occurred, the cooked items remained at elevated temperatures for considerable periods of time. Material flow through the facility during processing was not a consistent feature. As long as high processing and holding temperatures were the dominant considerations and not quality (to be obtained in conjunction with efficiency) than HACCP analysis would be of limited value. Regardless of the type of facility, HACCP analysis has the greatest impact and validity in a quality assurance program if material handling, the use of equipment and thermal processing are structured in detail and the program is capable of maintaining consistency in production scheduling. Stages in processing have to be structured and be predictable in order to (1) determine critical control points (2) impose sanitation procedures and (3) establish time-temperature constraints on materials and equipment. As noted above, a HACCP study is essentially custom-made for each facility and item.

Rather than resembling a commercial facility the F.E. Warren AFB was more closely related to the more unstructured centralized food preparation in-house feeding facility.

For this type of system, common equipment is used for a wide variety of products produced simultaneously or sequentially and personnel tend to perform more varied tasks.

It is apparent that different approaches to HACCP can be undertaken, depending upon the facility. These are:

(1) To program a product through the facility in a known series of processing stages on specific equipment and expose it to known temperature-time profiles.

(2) For facilities where (1) is not possible but where certain equipment such as capping or filling machines are in continuous use, then a HACCP can be applied only to these operations and the program supplemented with general constraints for sanitizing and processing.

Processing at F.E. Warren AFB was, with the exception of the capping machines, a manual operation. Commonly employed options such as slicing machine, automatic

fillers or recording thermometers were not employed. The production rate during the study was operating a half-capacity and therefore neither the facility nor personnel were stressed. For these reasons, and in spite of the fact that the manufacture of any given menu item is straightforward and conventional, a complete HACCP analysis for the F.E. Warren AFB was not suggested. A sensible approach at present appears to be the imposition of processing constraints and guidelines imposed at different stages of production and which could be presented as a supplement to production guides. This approach would also be useful if improvements in product quality are considered and more stringent temperature control required. As the operation expands and if processing becomes more structural in terms of scheduling and predictability, the HACCP analyses and a more formal Quality Assurance Program can be instituted.

RECOMMENDATIONS

1. That a program be initiated at the F.E. Warren AFB to optimize the quality of their production items and the efficiency of their production procedures.

2. The Food Microbiology Group of NDC should participate in a study to verify that any innovations in production procedures will result in products able to meet microbiological constraints. For a HACCP program to be established a sophisticated procedure for material handling and for monitoring temperature and times must be utilized. This is not difficult if commercially available instrumentation is utilized.

3. The Food Microbiology Group should design the most economical and effective monitoring procedures for the FFPM facility and train appropriate personnel responsible for conducting the quality control program in food microbiology.

4. The present quality control program could be made more effective by initiating the following:

a. Replace the blender cups used for APC with the stomacher apparatus and disposable plastic bags. The incubator at the facility was not accurate and the incubation temperature for APC should be lowered. The incubator was of insufficient size for the volume of tests being performed.

b. Consideration should be given to using a direct technique such as the Droplette method or an indirect method such as the radiometry for microbial analysis.

c. Improved isolation media and new rapid and precise taxonomic kits should be employed for the isolation and identification of *Escherichia coli*. An allowable level of *E. coli* should be established but if a zero level is required it should refer to enteropathogenic *E. coli*.

d. More use should be made of disposables such as pipettes, plates, tubes, etc.

e. A research microscope should be made available.

f. It would be more effective if the laboratory was located in or adjacent to the production facility.

g. Plastic, disposable gloves should be worn in operations where direct contact with food is a problem during processing or portioning. Germicide treatment will decrease but not eliminate microbial contamination on skin but germicides are maximally effective on clean surfaces and the duration of their effectiveness varies with environmental conditions.

h. Sanitation should be monitored more frequently with either Rodac plates or by the modified swab technique. Both are easy to use and to not unduly tax a monitoring system.

i. Foil packs should be redesigned so that the lids do not collapse after stacking and during storage and shipment. This would minimize freezer burn of the contents, as was noted at the missile site (see Appendix, Additional observation No. 13). Also, closely monitor stored items so that outdated items (according to SAC Regulation 146-1) are not being served to the consumer.

5. Processing would be improved by:

a. Thermal processing should be controlled by the use of thermometers, and recording thermometers should be made available.

b. More effective sanitizing equipment should be obtained. This would include additional hoses with jet nozzles and, if necessary, a chlorine generator.

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APPENDIX

ADDITIONAL OBSERVATIONS

The following observations of the manufacturing procedures were made during this study:

1. Roaches were visibly evident.

2. Personnel periodically sanitized their hands in an iodine-detergent solution and cleaned their nails with a bristle brush. This is not sufficient for certain food handling operations where disposable gloves should be worn.

3. Surfaces were often cleaned without the use of detergent. Wiping of surfaces was often performed with sponges.

4. A long hose was used for washing and filling a kettle with water for cooking. It often was lain on the floor and its open end – which was frequently dipped into gravies, etc., was never sanitized.

5. When filled and sealed containers were stacked for freezing, the liquid from the upper containers wet the lids of those below.

6. Thermometers were not routinely employed to check cooking temperatures.

7. If there was a delay in processing, partially and, at times completely cooked and panned food items, were placed in the refrigerator. This often resulted in a decrease of the items temperature into the danger zone (40 – 140 F; 4 – 60 C).

8. Cooking temperatures were uneven and often portions of the surface of panned items were burned.

9. The temperatures of the refrigerators were not accurately monitored.

10. Damaged or defective filled and sealed containers were accepted for freezing.

11. Empty aluminum containers were handled with bare hands during the filling operation.

12. Roast beef was initially cooked to the rare stage. However by the end of the 2nd heat treatment, it became partially dehydrated and thoroughly cooked.

13. A number of menu items were being served at the missile sites even though they were outdated. Other containers were found to be damaged and the exposed contents displayed freezer burn.

TABLE I

Evaluation of equipment by Rodac plates

	DATE					
		May			June	
ITEM	28	29	30	3	4	5
Table 1	S[a]	S				U,U[e]
Table 2	U[b]	S		S	S,S[e]	U
Table 13	S				S	S
Table 14	S			S,S[e]		
Table 15	S		U,U[e]	S	S	U,S[e]
Table 20				S		
Table 23			S			S
Table 25			S	S,S[e]	S,S[e]	S,S[e]
Table 31		U	S			
Table 32		S				
Table 39		U	U			
Utensils						
Rolling pin (wooden)	U			U,S(2)		
Spatula	U(2)[h],S(3)	U(2),S(3)	U,S(4)	U,S(3)	U(4),S	S(2)
Ladle	S					
Pots and Pans						
Pan	S					
Deep pot						
Collander	S	S		S	S(2)	S(2)
Kettle	S					
Mixing bowl	S	S(2)		S,U	S(:!),S[e]	S(2)[e]

TABLE I (cont'd)

Evaluation of equipment by Rodac plates

ITEM	DATE May 28	May 29	May 30	June 3	June 4	June 5
Pots and Pans (cont'd)						
Large kettle	S					
Deep pan	S(5)	S(4)	S(3),U	S(3)		
Deep pot	S(3)		S			
Small pan		S	S(2)			
Baking pan			S(4)			
Tilt fryer			S			
Cutting board	S,U(3)	S(2),U	S(2),U(2)	U[e](2),U(4)	S,S[e],U[g](3)	U[f]S,U[g,e](2)
SPL[c] – beginning	S			S	S	S
SPL – middle	S			S	S	S
SPL – end	U			U	S	S
SPL – front plate				U	U	S
SPL – side plate				U	U	S
SPL – capping plate	S					
LPL[d] – beginning			U	S	S	S
LPL – middle		U		U	U	S
LPL – end			S	S	S	U

TABLE I (cont'd)

Evaluation of equipment by Rodac plates

	DATE					
		May			June	
ITEM	28	29	30	3	4	5
LPL – front plate		S	U		S	S
LPL – side plate		S	U		S	S

[a]S–satisfactory, see text for definition.

[b]U–unsatisfactory, see text for definition.

[c]SPL–small packaging line, the beginning, middle and end being portions of the line prior to the capper. The front, side and capper plates being portions of the capping machine.

[d]LPL–large packaging line.

[e]Intensive Rodac plate sampling, see Table 4 and text.

[f]Each side of the same cutting board; one side was satisfactory.

[g]Greening occurred on the Rodac plates, the organisms were identified as *Pseudomonas aeruginosa.*

[h]The number in the parenthesis is the incidence of items having an S or U evaluation.

TABLE II

A comparison between intensive and distributive Rodac plating techniques

Surface	Method[a]	CFU/plate	Avg.	Rating[b]
Table	D	33,34,59,57,56,54,71,55,55,56	53	U
	I	77,73,92,68,36,31,49,54,38,50	57	S
Table	D	3,3,4,8,12,4,3,6,8,1	5	S
	I	17,10,9,11,13,16,15,11,10,6	12	S
Table	D	8,4,11,9,14,7,13,4,6,9	9	S
	I	10,14,13,14,19,13,9,18,18,8	14	S
Table	D	36,98,54,48,59,38,46,40,40,83	54.2	S
	I	47,40,44,52,51,35,23,32,41,27	39.2	S
Table	D	28,36,32,25,26,18,25,33,12,29	26.4	S
	I	29,29,34,17,29,29,38,37,25,22	28.9	S
Table	D	21,92,94,95,107,89,80,66,56,76	77.6	U
	I	82,123,122,112,101,110,104,96,109	106.0	U
Table	D	30,34,34,44,26,34,37,30,113,40	42.2	U
	I	27,36,26,28,26,41,46,44,54,41	36.9	S
Table	D	58,38,30,30,49,42,5,35,31,25	34.3	S
	I	20,43,32,31,27,25,29,7,9,1	22.4	S
Mixing bowl	D	6,0,1,2,3	2.4	S
	I	0,4,2,0,0,25,3,0,2,2	3.8	S
Mixing bowl	D	0,0,0,0,0	0	S
	I	0,0,0,0,0	0	S
Mixing bowl	D	0,0,0,0,0	0	S
	I	0,0,0,0,0	0	S
Cutting board	D	18,5,4,15,6	9.6	S
	I	11,7,5,5,7,4,5,9,12,6	7.1	S
Cutting board	D	7,TNTC(4)[c]		U
	I	8,18,11,TNTC(6)		U

Total number of surfaces monitored – 13
Surfaces for which methods are in agreement – 11

[a]D–distributive method; I–intensive method – see text for definition.

[b]U–unsatisfactory; S–satisfactory – see text for definition.

[c]TNTC–To numerous to count, parenthesis indicates number of plates TNTC.

KEY

A. PRODUCTION AREA

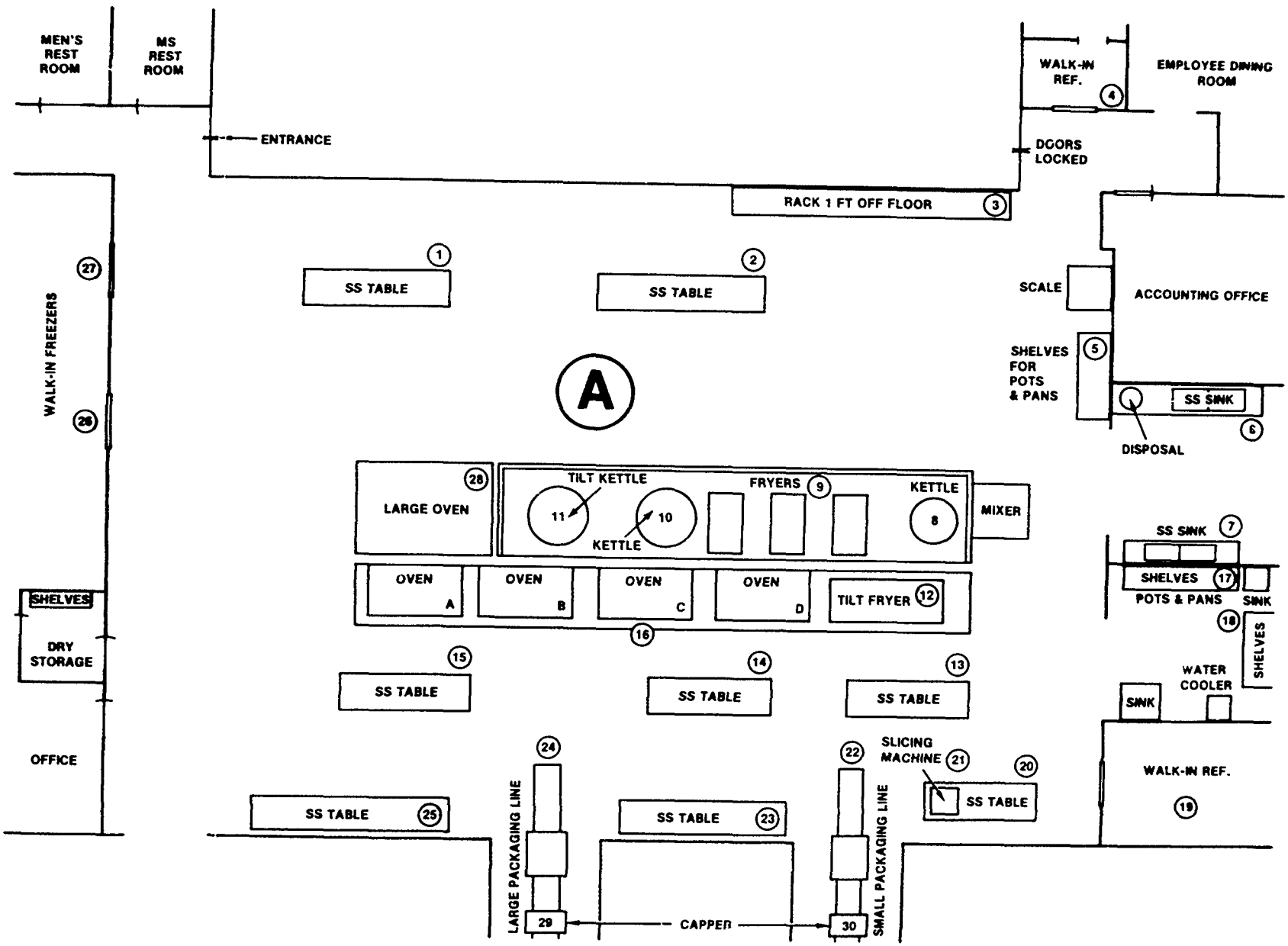
1. SS[a] table
2. SS table
3. Rack
4. Walk-in refrigerator
5. Shelves for pots and pans
6. SS sink
7. SS sink
8. Kettle
9. Fryers, A, B and C
10. Kettle
11. Tilt kettle
12. Tilt fryer
13. SS
14. SS
15. SS table
16. Ovens, A, B, C and D
17. Shelves for pots and pans
18. Shelves for pots and pans
19. Walk-in refrigerator
20. SS table
21. Slicing machine
22. Small filling and sealing line with sections A, B and C
23. SS table
24. Large packaging line with sections A, B and C
25. SS table
26. Walk-in freezer
27. Walk-in freezer
28. Large oven (removed)

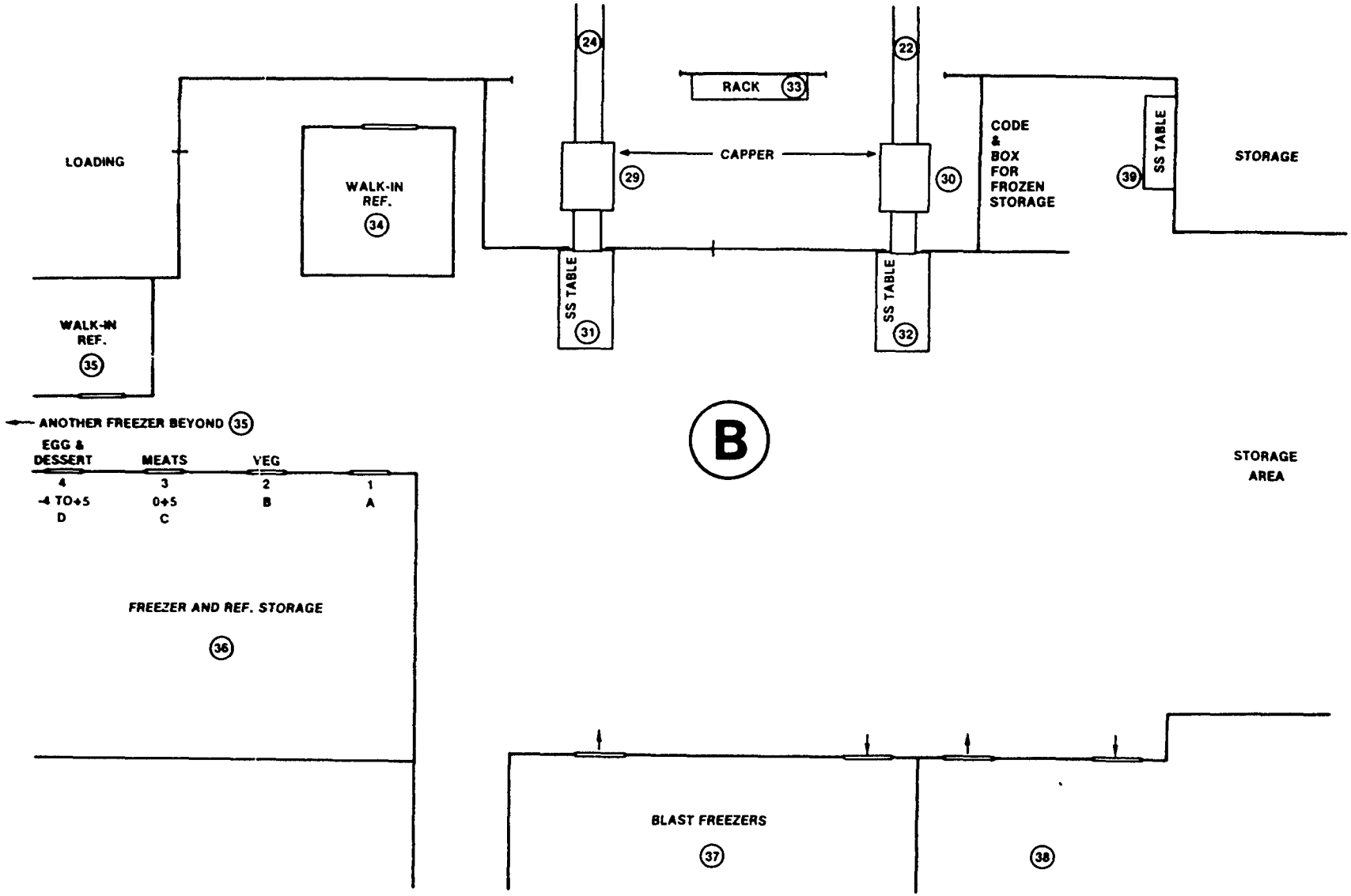
B. FREEZING AND STORAGE AREA

29. Capper – 24 C
30. Capper – 22 C
31. SS table
32. SS table
33. Rack
34. Walk-in refrigerator
35. Walk-in refrigerator
36. Freezer and refrigerated storage
37. Blast freezer
38. Blast freezer
39. SS table

[a]Stainless steel

FIGURE I. Schematic of the central preparation facility.


MEN'S REST ROOM
MS REST ROOM
ENTRANCE
WALK-IN REF.
4
EMPLOYEE DINING ROOM
DOORS LOCKED
RACK 1 FT OFF FLOOR
3
WALK-IN FREEZERS
27
26
1
SS TABLE
2
SS TABLE
A
SCALE
ACCOUNTING OFFICE
SHELVES FOR POTS & PANS
5
SS SINK
6
DISPOSAL
28
LARGE OVEN
TILT KETTLE
11
10
KETTLE
FRYERS
9
KETTLE
8
MIXER
OVEN A
OVEN B
OVEN C
OVEN D
TILT FRYER
12
16
SS SINK
7
SHELVES
17
POTS & PANS
SINK
18
SHELVES
SHELVES
DRY STORAGE
OFFICE
15
SS TABLE
14
SS TABLE
13
SS TABLE
WATER COOLER
SINK
WALK-IN REF.
19
24
22
SLICING MACHINE
21
20
SS TABLE
SS TABLE
25
SS TABLE
23
LARGE PACKAGING LINE
SMALL PACKAGING LINE
29
CAPPER
30


24
22
RACK 33
LOADING
WALK-IN REF. 34
CAPPER
29
30
CODE & BOX FOR FROZEN STORAGE
39
SS TABLE
STORAGE
WALK-IN REF. 35
SS TABLE 31
SS TABLE 32
ANOTHER FREEZER BEYOND 35
B
EGG & DESSERT
MEATS
VEG
4
3
2
1
-4 TO+5
D
0+5
C
B
A
STORAGE AREA
FREEZER AND REF. STORAGE
36
BLAST FREEZERS
37
38